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Challenges and Opportunities: A Systematic Review of AI Tools in Engineering Education

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Introduction

The integration of Artificial Intelligence (AI) into engineering education is transforming how students approach complex technical concepts and solve problems. With engineering disciplines covering a wide variety of complex technical topics, students face challenges in understanding and applying theoretical knowledge. AI technologies such as AI-assisted tutoring systems, performance predictions models, and generative AI tools are effective in enhancing student interactions with engineering curriculum improving student understanding and engagement [1][2]. By enabling real-time feedback, personalized learning experiences, and interactive problem-solving environments, AI tools are creating new opportunities for engineering education [3][4].

The advancement of AI technology, particularly generative AI systems such as ChatGPT fosters critical thinking and collaboration among students. In a study done by Abril students used AI tools such as ChatGPT to obtain and synthesize information. These students learned how to think critically about the questions they need to ask to lead them to the answer they needed [5]. Additionally, AI tools can be used to check answers and equations to provide a deeper understanding on complex engineering topics [6].

The integration of AI in engineering education also presents challenges. Students may develop and overreliance on AI tools and AI may negatively impact academic integrity [7]. Furthermore, concerns surrounding the ethical implications of AI include issues of bias, privacy, and inability to validate AI-generated information highlight the need for comprehensive training on the responsible use of AI [8][5]. Educators must consider these challenges to ensure that AI tools are integrated effectively into engineering curriculum.

This literature review explores the research question: How do different AI tools impact student learning outcomes in engineering education? This review provides an analysis of the impact AI has on undergraduate and graduate students in engineering education by evaluating the impact of AI tool use on student learning outcomes such as assessment scores, engagement, and retention. Challenges and opportunities associated with AI in engineering education are also discussed from a practitioner perspective with a focus on AI applications such as AI-assisted tutoring, performance prediction models, and tools for fostering collaboration and hands on learning. By analyzing recent studies, this review aims to synthesize current knowledge, identify gaps, and provide insight for educators and researchers on the impacts of AI in engineering education.

Methodology

The literature search was conducted using the Scopus database, which yielded 201 articles- an adequate number for this review- focusing on peer-reviewed journal and conference papers published between 2021 and 2025. The search employed the following Boolean search terms:

> "Artificial intelligence" AND "Engineering education" AND "GPA" OR "Grade Point Average" AND "Academic Performance" AND "Student Achievement" AND "Learning Gains" AND "Knowledge Retention"

This combination of terms found studies that explore the impact of AI tools on various aspects of student learning outcomes in engineering education.

To ensure the review focused on relevant studies, specific inclusion and exclusion criteria were applied. Only peer reviewed journal articles and conference papers published between 2021 and 2025 were included to capture recent advancements in this field, such as the development and release of Chat GPT and other generative AI tools. The scope was restricted to studies conducted within an academic context, excluding research focused on industry or non-academic environments. Articles were considered only if they were published in English due to language limitations within the reviewing team, and had reached the final publication stage, excluding preprints and work in progress papers. By limiting the selection to these criteria, the review focused on how AI impacts students learning outcomes in engineering education.

The search engine provided 201 articles from an initial search utilizing Boolean search terms and the inclusion and exclusion criteria. Two screenings were conducted by a team of three researchers. For the first screening each abstract was read to ensure it fit within the scope of the research question. As part of the first screening, abstracts that did not fit the scope of the project were identified and reasons for their exclusion were recorded. These reasons include non-engineering education related papers, papers not AI related, papers with focuses on developing AI rather than effects of AI use, and others including articles about students in other programs excluding engineering, and use of AI only for predictions in education, and the use of AI in industry. After this screening was complete there were 55 articles that met the requirements. Each category and the number of articles in each is shown in figure 1.

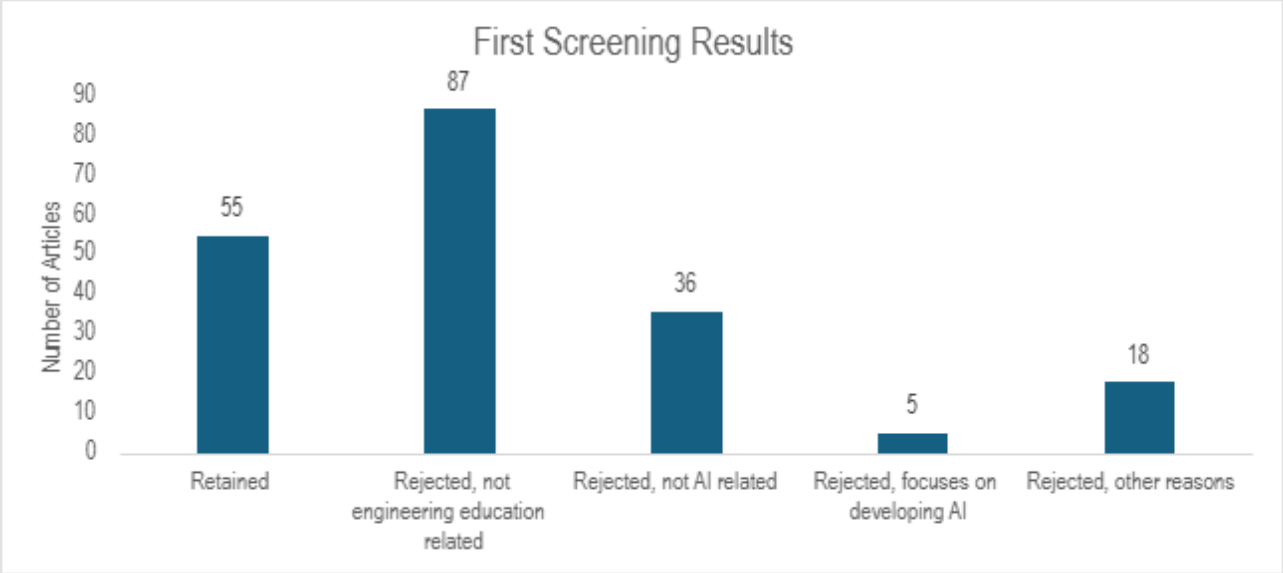

Fig 1. First screening results from Scopus.

The second screening required reviewers to read the article to determine if it answered the research question. If the content of the paper addressed the research question, the following information from the article was recorded in a table to tabulate results from all other selected studies: the population, sample size, types of AI used, application of AI, how learning outcomes were measured, positive and negative outcomes, and how the article answered the research question. After the second screening, 14 of the original articles were selected for inclusion in the

analysis. The positive and negative outcomes from each of the 15 articles relevant to this literature review are shown in table 1.

Table 1: Relevant studies after second screening

Authors	Student Engagement	Collaboration	Grades	Promote critical thinking	Deeper understanding and develop problem solving skills	Peronalize learning and Feedback	Overreliance on AI	Inability to check accuracy	Ethical concerns/Privacy concerns
′ousef (2022)	X								
Liao (2024)	X		X	X			X		
ueseca (2024)	X		X			X	X	X	
)uyang (2023)	X	X				X	X	X	X
Abril (2024)		X		X			X	X	
/idalis (2024)				X	X	X	X	X	
ureshi (2023)	X		X				X	X	X
gbese (2022)									X
Hazari (2024)					X	X	X		X
Niese (2024)	X		X	X	X	X	X	X	X
arayan (2024)			X	X			X		X
Yun (2024)	X				X		X	X	X
)veissi (2022)	X			X	X		X		X
Islam (2024)				X	X				
arquez (2023)	X				X	X	X		X

Results and Discussion

The included studies for this review focused on engineering or computer science students. Both undergraduate and graduate students were represented throughout the selected studies. Each study was conducted with a focus on students using AI in an educational setting and the results were given to show how AI impacts student learning outcomes. Both positive and negative outcomes were found and discussed in each article.

Most articles included in this review had similar findings regarding positive and negative outcomes of student AI use shown in table 1. The common positive outcomes from integrating AI into engineering education are improved engagement, collaboration, grades, critical thinking and deeper understanding of material with personalized feedback. A combination of these positive skills can better prepare engineering students for industry [9]. A study done by Hazari discusses the importance of integrating AI into education to prepare students for an AI driven world [9]. Common negative outcomes of AI use discussed in the articles include overreliance on AI, inability to check accuracy of information, and ethical and privacy concerns. These negative impacts need to be considered before integrating AI into engineering education.

Positive feedback

Engineering education includes technical material that can be difficult to understand; as a result, many students struggle to stay engaged in a traditional classroom setting. Yousef et al discussed providing students with online interactive learning platforms will increase students' engagement by personalizing the learning based on individual student needs, providing interactive virtual labs, and enhancing collaboration and social learning by connecting students through intelligent discussion forums [1]. Using AI and virtual laboratories allows hands-on learning in engineering which will not only increase student engagement, but also help students retain information better [10]. Additionally, AI makes it possible to provide students with interactive problems which can

promote understanding. For example, in computer science classes providing students with snippets of code from AI, students interact with AI to complete the code [2]. Additionally, in a study by Marquez et. al. generative AI was introduced into chemical engineering curriculum to aide in brainstorming for design [11]. AI tools can be useful in generating ideas for student group projects.

Engineering focuses heavily on collaboration and group work, both in industry and educational settings. AI-powered platforms facilitate group interactions, allowing students to collaborate on projects remotely and share real-time feedback. Facilitating group interactions is enhanced through AI tools that visualize group-level and individual-level participation metrics such as frequency and depth of discussions [4]. This held students accountable within a group setting to participate as students could see how their contributions compared to their peers. This fosters a deeper understanding of teamwork and improves communication skills. For example, collaborative coding environments introduced by Liao in computer science education help students develop the skills needed for industry [2].

The integration of AI tools in engineering education has led to improvements in student grades. Evidence shows there is a relationship between the use of generative AI in engineering education and improved grades for students by providing personalized learning assistance, engaging pre-class preparation activities, and providing real-time feedback [3]. Shown in a study by Huesca et al students who use these AI tools achieved an average learning gain of 52.8% which is higher than the 41.29% that students who don't use these AI technologies gain [3]. Studies show that AI-driven strategies enhance both quality and efficiency of student learning [2]. A study on 180 programming students showed that the average grade went up by approximately 15 percent after the integration of AI [2].

Critical thinking is a vital skill for engineering students. Integrating AI into engineering education can foster critical thinking and promote this skill development for engineering students. Narayan and Saharan report that tools such as AI-enabled predictors and generative AI systems can challenge students to evaluate outputs critically, identify errors, and propose alternative solutions [12]. These tasks encourage analytical thinking and allow students to propose alternative solutions.

Engineering disciplines cover complex technical material that students often have a hard time understanding. Providing students with AI tools can help them gain a deeper understanding of the material, ultimately improving their performance and confidence. In a study done by Wiese et al students used a computational notebook environment as an interactive tool that allowed students to manipulate AI models, observe outcomes, and refine their understanding through real time interactions [10]. AI tools can be used in other ways to improve students learning outcomes, for example, AI tutors allow students to receive instantaneous help on problems and concepts with AI providing a more advanced explanation on specific concepts than real-time tutors. As discussed by Yun et al the use of these tutors has reduced errors from real time tutors as well, deepening students' understanding of the concepts [13].

The computational power of AI can help students tackle complex engineering problems efficiently. AI allows students to use AI generated computing packages to simplify mathematical concepts, making it easier for them to grasp the underlying principles [14]. A course on industry technology allowed students to use AI tools to solve problems as they would in industry [14].

Additionally, by automating repetitive tasks AI tools allow students to allocate more time to critical thinking and problem solving [15]. AI allows students to spend more time evaluating data; evaluating and interpreting this data enhances the development of students' problem-solving skills [11]. Finally, AI's computational power positively impacts students' thinking. Students gain experience in forming thoughtful questions ultimately promoting the development of problem-solving skills [6].

The ability of AI to provide immediate feedback has revolutionized the learning process in engineering education. Personalized learning pathways help address individual student needs in understanding concepts covered in engineering education. AI-enabled performance prediction models and learning analytics have demonstrated the ability to personalize learning by providing timely feedback [4]; timely feedback allows students to stay more actively engaged in their learning.

Negative feedback

Although there are many positive outcomes in integrating AI into engineering education, there are negative outcomes that need to be considered. Overreliance on AI can result in a limited understanding of the material and hampers students' ability to innovate. There are many ethical issues associated with AI use in engineering education including using AI with limited knowledge on where the information goes when input into AI. There are privacy concerns with using AI when personal information is used. Finally, it is difficult to know if information received from AI is correct and accurate.

One concern discussed throughout the literature is that students can rely heavily on AI tools, such as ChatGPT, for academic tasks. Overreliance on AI can lessen critical thinking and problem-solving skills, particularly when students rely on AI-generated solutions without attempting to solve a problem and understand the concepts [7]. In a study done by Qureshi on undergraduate students in computer programming courses ChatGPT was implemented to help with coding assignments. Results of this study showed that there was an increase in scores on simple coding assignments, however, on more challenging coding assignments the solutions generated by ChatGPT were often inaccurate or incomplete, leaving students to debug the code. Students who used ChatGPT often struggled more on this complex problem due to not understanding how to debug their code [7].

Over time, this reliance can lead to a limited understanding of the concepts taught to engineering students. Addressing these issues requires integrating teaching strategies that encourage students to use AI as a supplementary tool rather than a source of knowledge.

While the engineering industry increases reliance on the use of AI, currently students are not being taught ethics related to AI. If ethics behind the use of AI are not taught in engineering classrooms, there is a greater risk of ethical principles being compromised [8]. Without proper understanding of ethical implications, students may misuse AI leading to potential breaches of privacy. Abgese proposes that AI ethics be introduced to students when integrating AI into their education [8].

A major drawback of relying on AI tools is the difficulty in validating the accuracy of the information provided. AI tools can sometimes produce incorrect or misleading content, known as

hallucinations, and students who lack the skills to critically evaluate the outputs may have errors in their work [5]. This challenge emphasizes teaching students how to cross-check AI generated solutions with a verified source and approach tools critically to ensure their academic and professional outputs are accurate and reliable.

The articles reviewed for this literature review discuss potential concerns of integrating AI into engineering education including privacy and ethical concerns, an overreliance on AI, and inability to validate the accuracy of the information provided. With these negative outcomes educators should be conscientious of how they are integrating AI into their classroom setting.

Limitations

There are limitations with this review that should be considered including the use of Scopus as the only search engine, no significant longitudinal data, and the rapid development of AI. More search engines could have given more articles to draw from resulting in further implications on positive and negative outcomes of integrating AI into engineering education. One of the other limitations that exists is how fast AI is developing. The applications for AI use are expanding rapidly, and AI tools are being integrated into existing computational tools which continue to impact how it is used in an educational setting. By the time this article is published, it is likely AI will have footholds into many areas not published when this study was conducted. Finally, because AI is relatively new, there is a lack of longitudinal studies that show how AI impacts students as they enter the workforce. This shortcoming will soon change, however, as AI matures, and researchers continue to publish findings on its use.

Conclusion

This systematic literature review synthesizes research conducted on the use of AI in engineering education and looks to explore the research question: How do different AI tools impact student learning outcomes in engineering education? Results indicate that both positive and negative outcomes result from integrating AI into engineering education. The common positive outcomes found in these articles include better collaboration, higher grades, deeper understanding of the material, problem solving skills, personalized feedback and learning, and critical thinking. In contrast, the common negative outcomes include privacy and ethical concerns, an overreliance on AI, and the inability to validate the accuracy of the information provided. These outcomes indicate that if AI is integrated correctly into engineering education there are many positive outcomes that exist better preparing students for industry.

Future Work

Future research that can originate from or build on the present study includes discovering how AI affects students after they enter industry. The impact of AI on engineering students' knowledge of technical material taught in engineering education also continues to remain unknown. A longitudinal study following students throughout their education and into industry could answer some of the unknowns about how AI impacts students as they enter industry.

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